International Journal of Electronics, Communication & Instrumentation Engineering Research and Development (IJECIERD)
ISSN(P): 2249-684X; ISSN(E): 2249-7951
Vol. 4, Issue 3, Jun 2014, 27-32

USE OF HEART RATE VARIABILITY FOR THE DETECTION OF THE DEPTH OF ANESTHESIA

PRIYANKA KADAM, ADITI ROHINI, PRIYANKA GAIKWAD, MONIKA BHAGAT & JYOTI WARRIER

Department of Biomedical Engineering, MGMCET, Navi Mumbai, Maharashtra, India

ABSTRACT

Automated drug administration by closed-loop systems has been proposed to optimize drug administration during anesthesia and sedation.General anaesthesia is associated with a reduction in heart rate variability (HRV) compared to awake situation. It is a measure of activity of the sympathetic and parasympathetic components of the autonomous nervous system due to Surgical stress. The system is designed to track a reference hypnotic depth level, while maintaining adequate analgesia. The hypothesis of reduction in HRV predicts different levels of an aesthesia depth. The objective of the work has been to develop a system which independently controls the intravenous infusion rates of the analgesic drug remifentanil. The system is designed to track a reference hypnotic depth level, while maintaining adequate analgesia.

KEYWORDS: HRV, ECG, BIS, Anesthesia, Analgesia, Spectral Analysis

INTRODUCTION

Anesthesia drug delivery involves the continuous administration of a combination of drugs with frequent adjustments to maintain normal cardio respiratory vital signs during surgical stimulation. Recent advances in nervous system monitoring technology have yielded a new set of real time parameters to capture the effect of these drugs on the patient's state. As a result, automated feedback control of anesthetic drug delivery to a pre-defined set point can be a means for providing the patient with a titration specifically adjusted to his or her needs. In automated close loop drug delivery system that integrate three parameters of general anesthesia hypnosis, analgesia and neuromuscular block. Drugs are automatically delivered to maintain the target values.Heart rate variability (HRV) describes variations between consecutive heartbeats. The regulation mechanism of HRV originates from sympathetic and parasympathetic nervous systems.

Thus, HRV can be used as a quantitative marker of the autonomic nervous system, and HRV parameters have been used to predict the mortality risk in patients with heart disease, such as life threatening arrhythmias and acute coronary events. The measurement of the Heart Rate Variability (HRV) is a rather new technique to quantify the analgesia and could be, in combination with a parameter derived from vital function, a valid parameter for analgesia controller.

ANALGOSCORE

A pain score is derived from HR to control the dose of analgesia. This score is calculated by measuring offset percentage between measured and target value of HR. Analgoscore scale ranges from -9 (very profound analgesia) to +9 (very superfecial analgesia). The analgoscore i.e.pain scrore which controls the analgesic drug remifentanil in automated drug delivery system.

- **Clinical Implication**

Measurement of heart rate variability (HRV) is an easily accessible window into autonomic activity. Analysis of heart rate variability (HRV), that is the variability of R-R in the electro-cardiographic (ECG) signal, has been widely used as a measure of activity of the sympathetic and parasympathetic components of the autonomous nervous system. Surgical stress stimulates the sympathetic nervous system and in some cases the parasympathetic as well. Suppression of this stimulation routinely is achieved by opioids during general anaesthesia, which markedly depresses HRV and therefore it has been suggested as a measure of depth of anaesthesia.

The induction of anaesthesia with both propofol and remifentanail is associated with a reduction in HRV compared to preanaesthetic values, first goal of this study was to test the hypothesis that general anaesthesia with pro-pofol or sevoflurane would affect HRV in a way depending on the depth of anaesthesia as it is expressed by Bispectral Index (BIS).

- **Clinical Application**

Thus, spectral analysis of HRV provides a measure for quantifying sympatho-vagal balance in its physiological range.Since it is also a striking reduction produced by most anaesthetic agents and HRV are investigated as measures of anaesthetic depth.

- **Cardiovascular Signs**

A slowing heart rate indicates surgical anesthesia. An increase in rate (tachycardia) during the performance of a surgical procedure often indicates that the depth of anesthesia is not adequate. A decrease of rate (bradycardia) during surgery may signify an excessive dose of anesthetic. Opioids, xylazine, and vagal reflex activity can cause bradycardia.

- **Placement of Electrode & Lead Configration**

In order to record to record ECG, clamp electrodes or pad electrodes are connected to patient's limbs in standard format as shown in figure. The Bipolar Lead configuration represents a voltage difference between two selected sites.

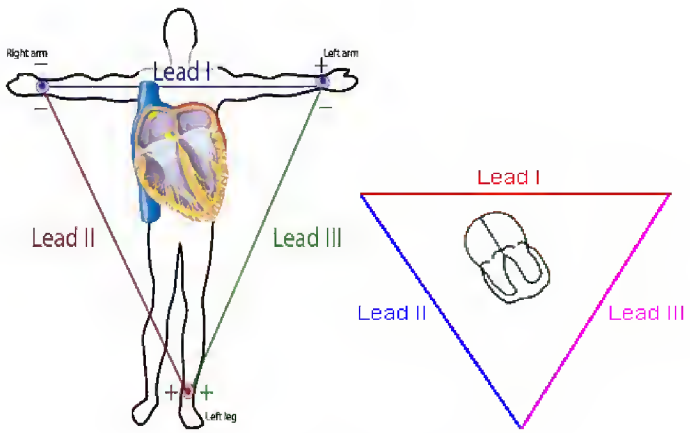

Figure 1: Einthoven's Triangle

BLOCK DIAGRAM

To derive the Analgesia score the first stage is an acquision of ECG from patient. From the HF/LF ratio Analgoscore is derived which is calculated from the Power spectral analysis.

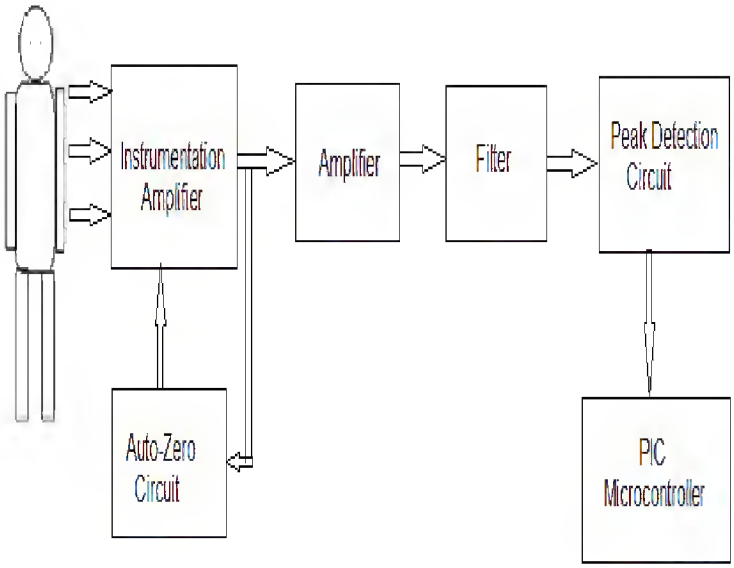

Figure 2: Block Diagram

- **Instrumentation Amplifier**

An important stage of all biopotential amplifiers is the input preamplifier which substantially contributes to the overall quality of the system. The main tasks of the preamplifier are to sense the voltage between two measuring electrodes while rejecting the common mode signal, and minimizing the effect of electrode polarization over potentials. A differential amplifier has two types of inputs: common mode input CM and Differential mode input DM. What one needs is to amplify Dm and reject CM. Thus CM gain has to be low and DM gain has to be high. ln instrumentation amplifier, buffer is used to buffer the signal. However, DM gain can be quite high, typically 10 or even 100. In next stage, the two signals get fed to a differential amplifier, whose CM gain is pretty low and can be made zero by an external pot. Differential amplifiers are used to make sure that noise from the inputs are not amplified thus yielding a higher integrity signal.

- **Auto Zero Circuit**

Nulling amplifier is to correct offset error voltages. This is simply a model used to describe the basic technique used in auto-zero correction. Offset errors from all sources are corrected. This error correction occurs during every period of the auto-zero clock so the amplifier provides a continuous error correction. The overall low offset voltage of the total auto-zero amplifier is maintained. lt also corrects for any long term drift or aging effects that could change offset voltage over time.

- **Non-Inverting Amplifier**

ln this configuration, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes "Positive" in value in contrast to the "lnverting Amplifier" circuit. The result of this is that the output signal is "in-phase" with the input signal. Feedback control of the non-inverting amplifier is achieved by applying a small part of the output voltage signal back to the inverting (-) input terminal via a R*f* - R2 voltage divider network, again producing negative feedback. This closed-loop configuration produces a non-inverting amplifier circuit with very good stability, a very high input impedance, Rin approaching infinity, as no current flows into the positive input terminal, (ideal conditions) and a low output impedance.

$V_{out} = V_{in} (1+R2/R1)$.

- **Peak Detection**

Peak Detection using hardware consists of Band pass filter, Absolute value circuit, Peak detection circuit, Comparator and Monostable multivibrator for the detection of the R peaks.

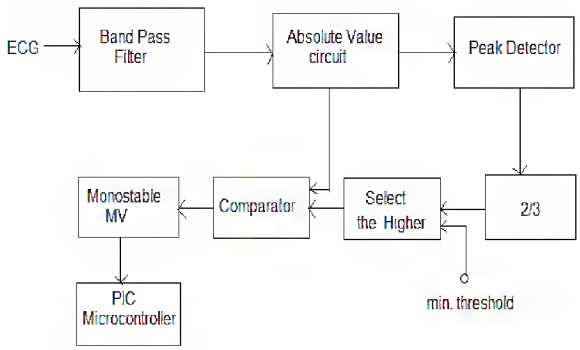

Figure 3: Block Diagram of Adaptable Threshold QRS Detector

- **Band Pass Filter**

The filtering method depends on the type of noises in ECG signal. In some signals the noise level is very high and it is not possible to recognize it by single recording, it is important to gain a good understanding of the noise processes involved before one attempt to filter or preprocess a signal.

The ECG signal is very sensitive in nature, and even if small noise mixed with original signal the characteristics of the signal changes. Data corrupted with noise must either filtered or discarded, filtering is important issue for design consideration of real time heart monitoring systems, designed amplifier using instrumentation amplifier AD620 (Analog Devices) to bring the peak value into a range of 1v; having gain of 1000. For collection of ECG signal it has used band pass filter with cutoff frequency 0.5Hz-150 Hz. The band pass filter the frequency range of 0.04 Hz ~ 150 Hz. The filter is implemented by cascading a low-pass filter and a high-pass filter. The data of low-pass and high-pass filter are implemented by simple RC components. The desired output from our ECG amplifier is a 1V maximum amplitude signal, with a frequency range of 0.5 to 100 Hz. Therefore, our amplifier will have a gain of 1000 and the filter will have a pass band of 0.5 to 100 Hz.

- **Absolute Value Circuit**

The output of this circuit is a positive voltage that represents the absolute value of the input, whether positive or negative. So that the peak of the QRS complex converts to a positive.

- **Peak Detector Circuit**

Peak detector that measures the positive peak values of the input. Hence the positive peak from the Absolute value circuit can be detected. Higher value from the threshold or the 2/3rd of the peak is selected. Here a logic circuit used to select the higher from the two inputs.

- **Comparator and Multivibrator**

It compares the absolute value and the higher value of the threshold The sharp "R wave" pulse needs to be detected using a circuit composed of a comparator and a monoshot. The mono-stable multivibrator is used to produce a pulse of standard width and amplitude for each output pulse of comparator, in order to derive a uniform frequency.

- **PIC Microcontroller**

According to the LF/HF ratio the Analgesia scale is derived. The microcontroller will be programmed to control the operation of the delivery system. After selecting a suitable dose and period, the microcontroller gives signal that drive the stepper motor and consequently driving the syringe pump to deliver the required dose at the end of each assigned time cycle. Feedback is provided from the patient, it will check real time parameter and the incremental dose is calculated and that dose is provided precisely.

LF/HF RATIO

Two major spectral components were observed. Alterations in the LF/HF ratio with pharmacological blockade suggest that the control of HRV over these two spectral regimes is the LF component (0.4–1.5 Hz) regulated by both sympathetic and vagal inputs and the HF component (1.5–4 Hz) predominantly parasympathetically mediated. The division into frequency bands in this study was performed according to the recommendation LF-band (0.04–0.15 Hz), HF-band (0.15–0.40 Hz). The decrease in the parasympathetic mechanism produced by atropine was reflected by a slight increase in the LF/HF ratio. The LF/HF ratio appeared to follow the reductions of sympathetic activity produced by propanol. From these results, the LF/HF ratio seemed to be a convenient index of parasympathetic and sympathetic interactions. Therefore, power spectral analysis of heart rate variability may provide a very powerful noninvasive technique for assessing autonomic nervous activity. Two major spectral components were observed. Alterations in the LF/HF ratio with pharmacological blockade suggest that the control of HRV over these two spectral regimes is the LF component (0.4–1.5 Hz) regulated by both sympathetic and vagal inputs and the HF component (1.5–4 Hz) predominantly parasympathetically mediated. Total power, LF power, HF power, and LF/HF ratio of frequency-domain variables of HRV decreased significantly after parasympathetic blockade with atropine and after combined sympathetic and parasympathetic blockade. All time-domain parameters of HRV (SDNN, SDANN, RMSSD) decreased significantly after parasympathetic blockade with atropine and after combined sympathetic and parasympathetic blockade.

TIME-DOMAIN AND FREQUENCY-DOMAIN MEASURES OF HRV

- **Time-Domain Measures**

The time domain parameters are calculated directly from the RR interval time series. The time domain measures are the mean and standard deviation The Standard Deviation is a measure of variation of value of RR interval. Variance is a square of standard deviation. Variance is equal to total power spectral analysis. In the time domain, the mean R-R interval (RR_{mean}), median R-R interval (RR_{median}), standard deviation of all normal R-R intervals (SDNN), standard deviation of averages of normal R-R intervals (SDANN), and the square root of mean of squared differences between adjacent normal R-R intervals (RMSSD) were calculated directly from the sequence of interevent times. The mean HR (HR_{mean}) was calculated as the mean of the sequence of the reciprocals of the interevent times. Furthermore, as HR changes per second occurring after administration of atropine and propanol may affect HRV, an additional parameter was calculated: the coefficient of variance (CV), defined as the standard deviation of R-R intervals/ RR_{mean}.

- **Frequency Components Represent Distinct Autonomic Inputs**

Mean HR is subject to many diverse control mechanisms and is not a reliable marker of autonomic activity and tone. Because the frequency components of the HR spectra are affected by both the sympathetic and parasympathetic nervous systems, HRV analysis allows quantification of the respective contributions. We observed two major spectral

components. Diminished modulation of vagal activity after administration of the parasympathetic antagonist atropine was established by a decrease in time- and frequency-domain measures of HRV. In the frequency domain, both the HF and LF components of the HRV spectrum were significantly reduced. Whereas HF power is widely accepted as a marker of cardiac parasympathetic control, the underlying control of the LF power has yet to be fully elucidated. The finding that atropine significantly reduced LF power is consistent with a large parasympathetic component to LF power, although it may somewhat reflect the selection of 1.5 Hz as the LF/HF division.

CONCLUSIONS

Analysis of heart rate variability (HRV), that is the variability of R-R in the electro-cardiographic (ECG) signal, has been widely used as a measure of activity of the sympathetic and parasympathetic components of the autonomous nervous system. Suppression of this stimulation routinely is achieved by opioids during general anaesthesia, which markedly depresses HRV and therefore it has been suggested as a measure of depth of anaesthesia.

ACKNOWLEDGEMENTS

We would like to thank our guide **Prof. Jyothi Warrier** and Head of the Department **Dr.G.D.Jindal** for giving us the freedom to select our desired topic for the project work and supporting us in our endeavors.

REFERENCES

1. Akselroad S, Gordon D, Madwed JB, Snidman NC, Shannon DC, Cohen RJ. Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. Science 1981; 213: 220-2.
2. J. Parak, J. Havlik, "ECG SIGNAL PROCESSING AND HEART RATE FREQUENCY DETECTION METHODS," Department of Circuit Theory, Faculty of Electrical Engineering Czech Technical University in Prague.
3. J.W.Sleigh,J.Donovan, "Comparision of BIS,95% Spectral edge frequency & Approximate entropy of EEG, with changes in Heart Rate Variability during induction of Anesthesia," Anesthesia Dept., Wikato Hospital, Hamilton, New Zealand.
4. Webster, John G., Medical Instrumentation: Application and Design. 3rd Ed. Philadelphia:W.B. Saunders Company, 1998.
5. Pomeranz B, Macaulay RJB, Caudill MA, et al. Assessment of autonomic function in human by heart rate spectral analysis. Am J Physiol 1985; 248:151-3.
6. Nasim Karim 1, Jahan Ara Hasan 2 and Syed Sanowar Ali 3,"HEART RATE VARIABILITY – A REVIEW",1Pharmacology Department, Bahria University Medical & Dental College, Karachi, Pakistan, 2Gynaecology and Obstetrics, Dow University of Health Sciences (DUHS), Karachi, Pakistan.3Community Health Sciences, Ziauddin University, Karachi, Pakistan Journal of Basic and Applied Sciences Vol. 7, No. 1, 71-77, 2011 ISSN: 1814-8085.